



Calibration and validation data for circumpolar Arctic infrastructure mapping

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CALIBRATION AND VALIDATION DATA FOR
CIRCUMPOLAR ARCTIC INFRASTRUCTURE MAPPING

This report describes infrastructure data sources available for calibration and validation of a remote-sensing based infrastructure mapping algorithm for Arctic infrastructure. The report is written as part of the EU H2020 funded Nunataryuk project and filed as deliverable 6.1.

October 2018

Front page illustration: Sisimiut, Greenland. Photo by Thomas Ingeman-Nielsen.

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2 Introduction

Current remote sensing methodologies identify infrastructure collectively independently of type, size, shape and usage patterns. Traditionally only build up areas are considered.

As part of the Nunataryuk project, a new, largely automated algorithm for infrastructure classification is in development. It will be based on Copernicus Sentinel1 (Synthetic Aperture Radar) and Sentinel2 (multi-spectral high-resolution) data. A combination of the two types of sensors will distinguish different surface structures and materials. Build up areas can be specifically identified using the SAR data. Sentinel2 is relevant to distinguish different surface spectral properties. Artificial surfaces will be identified in a first step. Post-processing shape, topology and other relevant parameters of the identified features will target land use categories such as transportation.

Comprehensive ground truth data are required to test the capabilities of the satellite data to distinguish between different types of infrastructure relevant for the project and to quantify the uncertainties for mapping of the different types. Therefore, the ground truth dataset needs to include infrastructure and non-infrastructure polygons. In order to quantitatively assess the results, a categorization into different surface types is required, as uncertainties are expected to differ between them.

This deliverable report describes the status of a survey undertaken to identify existing sources of circumpolar Arctic and regional infrastructure data available to provide such ground truth data for calibration and validation of the developed algorithm.

The report also documents the production of new local data sets from Svalbard and Greenland, providing very accurate and high resolution positional information about different types of infrastructure in those regions, and providing feature attributes such as type of material, shape of the structure etc. needed to ground truth the categorization into different infrastructure types.

3 Existing sources of Arctic infrastructure information

This section provides a description of some global, pan-Arctic and regional data sources, and the kind of infrastructure information available from those sources. The survey is non-exhaustive, and additional sources are likely available. However, the current list of sources cover the entire area of interest, and provides a solid foundation for calibrating and validating the intended circumpolar Arctic infrastructure mapping output. Links are provided to each data source, as well as an explanation of the licensing terms for each product/provider.

3.1 Global and pan-Arctic data sources

3.1.1 Natural Earth

Natural Earth is a public domain map dataset available at 1:10m, 1:50m, and 1:110 million scales, featuring tightly integrated vector and raster data (<https://www.naturalearthdata.com/>). The database includes a complete set of physical themes, such as coastlines, rivers, lakes, glaciated areas etc. It also includes cultural themes like country borders and populated places, and infrastructure themes (subset of the cultural themes) with airports, ports, railroads and roads. Each theme is compiled from other external sources and is well-documented (online documentation for each theme). Infrastructure features are line features (roads, railways) or point features (ports, airports). The accuracy of the features is variable. The accuracy of road and railway features seem to be on the order of 10 to 20 m. Ports and airports are represented either by a kind of centroid location, or are geocoded based on e.g. a town location, and thus coordinates may in some cases be quite inaccurate. The infrastructure data is incomplete for most Arctic regions. As an example, no roads and very few ports and airports are registered for Greenland and Svalbard.

The Natural Earth Data are released in the public domain, and no permissions or crediting are required for reuse of any kind.

3.1.2 The Arctic Marine and Aviation Transportation Infrastructure Initiative

The Arctic Maritime and Aviation Infrastructure Database (<https://arcticinfrastructure.org>) was developed under the guidance of the Arctic Council's Sustainable Development Working Group. It includes themes of port and airport infrastructure in the Arctic, represented as point features. The accuracy of the features depend on the source data used in the compilation, and the coordinates of features may be quite inaccurate.

These datasets are provided by the Institute of the North and the Arctic Council's Sustainable Development Working Group, and may be used for informational purposes only. They may not be used for commercial purposes. There is no other licensing information specified.

3.1.3 OpenStreetMap

OpenStreetMap (OSM, <https://www.openstreetmap.org>) is a collaborative project in which nuanced geographic information worldwide is shared. From Geofabrik's free download centre (<http://download.geofabrik.de/>), OSM data can be extracted by continent, country or region, as shape files or as OpenStreetMap XML Data files. The shape files only contain a limited set of infrastructure related features, such as roads and railways, whereas the XML files contain the full dataset, including airfield features etc.

Since the database is community driven, accuracy is variable, and data should be compared and crosschecked with authoritative data sources to ensure accuracy. In Greenland, for example, it is difficult to distinguish established roads from tracks and e.g. snow machine routes in open countryside.

OpenStreetMap data are licensed under the Open Data Commons Open Database License (ODbL), which allows free usage of the data and production of derivative products as long as the source is attributed, and derivatives are similarly licensed.

3.2 Regional data sources

3.2.1 2.2.1 Alaska

The main data source for infrastructure in Alaska is the Alaska Department of Transport & Public Facilities (ADOT&PF, <http://http://dot.alaska.gov/>). ADOT&PF makes available shape files of Alaska infrastructure from their data repository (<http://www.dot.alaska.gov/stwdplng/mapping/shapefiles.shtml>), including road centrelines, polygons and surface material (paved/unpaved), harbours, ferry terminals and public airports.

The data provided is the property of ADOT&PF, and may not be used in commercial products. It is unclear from the license if reproduction in educational and not-for-profit derivatives is allowed, and thus a formal permission should be obtained before usage of this data in Nunataryuk products.

The main roads and their real-time conditions can also be found in the online GIS interface at <http://511.alaska.gov/alaska511/mappingcomponent/index>. Winter transportation roads and their maintenance map are available via the link: <http://dot.alaska.gov/stwdmno/wintermap/index.shtml>.

3.2.2 Canada

The Canadian Government operates a geographical data repository at <http://geogratis.gc.ca/>. Physical and administrative themes are provided, and specifically for infrastructure, themes describing the road and railway networks and airport and ferry routes may be downloaded as shape files from the interactive repository web-interface (http://ftp.geogratis.gc.ca/pub/nrcan_rncan/vector/index/html/geospatial_product_index_en.html).

Each shape file includes feature attributes, such as road type or runway length etc. Data from this site is provided under the Open Government Licence - Canada, which allows free use of the data for any purpose,

as long as an attribution statement is included, and a link to the license is provided if possible.

(<https://open.canada.ca/en/open-government-licence-canada>)

Information on winter roads is available on each Canadian Province website. The website for Northwest Territories is <https://www.inf.gov.nt.ca/en/services/highways-and-ferries>, where the highway condition map and winter roads information are available, although not in data format applicable for mapping purposes.

3.2.3 Greenland

Asiaq - Greenland Survey provides official map data for Greenland. A web interface is available at <http://www.nunagis.gl>, which can be used to browse map and administrative themes, and download features from smaller regions. Through an ftp-service accessible from the Asiaq website (<http://www.asiaq-greenlandsurvey.gl/kortforsyning/>, at time of writing only available in Danish), the full data set can be downloaded as an ESRI geodatabase.

This database contains themes with features representing buildings, roads, airports, harbour facilities and more, with coordinates at decimetre to meter scale accuracies. The ftp-service should be accessible at <ftp://ftp.asiaq.gl/>. Login information is available at the Asiaq website (<http://www.asiaq-greenlandsurvey.gl/kortforsyning/>).

The Greenland geodata is provided under a non-restrictive, free-use policy, provided attribution statement is included (e.g. data provided by Asiaq - Greenland Survey).

3.2.4 Svalbard

With regard to the geographical information for Longyearbyen, a web interface is available here:

<http://lokalstyre.maps.arcgis.com/> and for local planer, including buildings, is available here:

<http://lokalstyre.maps.arcgis.com/apps/webappviewer/index.html?id=91ec98bf5ff44ac188ae06eac98b0b9d>

In addition to the above two links, official documents regarding the map information can be downloaded at <https://www.lokalstyre.no/arealplan.260471.no.html>

The themes are not downloadable. However, the local authority may be contacted to order such information. The contact information is available at <https://www.lokalstyre.no/kart-og-oppgaaling.247424.no.html>

As per October 2018, the contact persons are:

- Henning Furø, Engineer, Tel: 924 22 977, email: Henning.Furo@lokalstyre.no
- Kjersti Olsen Ingerø, Technical chief, Tel: 90 22 74 45, email: kjhol@lokalstyre.no

The themes supplied for the compilations in described in this report include polygon features representing buildings of various purposes and roads within Longyearbyen. The accuracy of the coordinates reaches decimetre accuracy.

We are currently investigating the licencing conditions of the infrastructure themes for Longyearbyen.

3.2.5 Russia

At the time of writing, we have not identified regional sources of free, downloadable geographical themes from the Russia and the Siberian Arctic. Several regions have data available online to registered users, e.g. Jamalo-Nenetskij autonome okrug at http://tbd.ru/eks/eks_support.php, and several web-interfaces with map data are available, e.g. Murmansk municipality at <http://93.170.9.3/map>.

3.3 Pan-Arctic compilation data sets

As part of the Nunataryuk project, pan-Arctic data sets on settlements and populations and on road accessibility will be compiled.

- 1) A pan-Arctic settlement database including all settlements with more than 500 inhabitants has been compiled by Nordregio, and is available at <https://doi.pangaea.de/10.1594/PANGAEA.895745>.
- 2) A pan-Arctic road access database is under compilation by Nordregio, based on the above-mentioned pan-Arctic and regional sources. The database is expected to be available in the first quarter of 2019.

These datasets will be published on the Pangaea repository under the CC-BY-SA license (Creative Commons Attribution-ShareAlike 4.0 International).

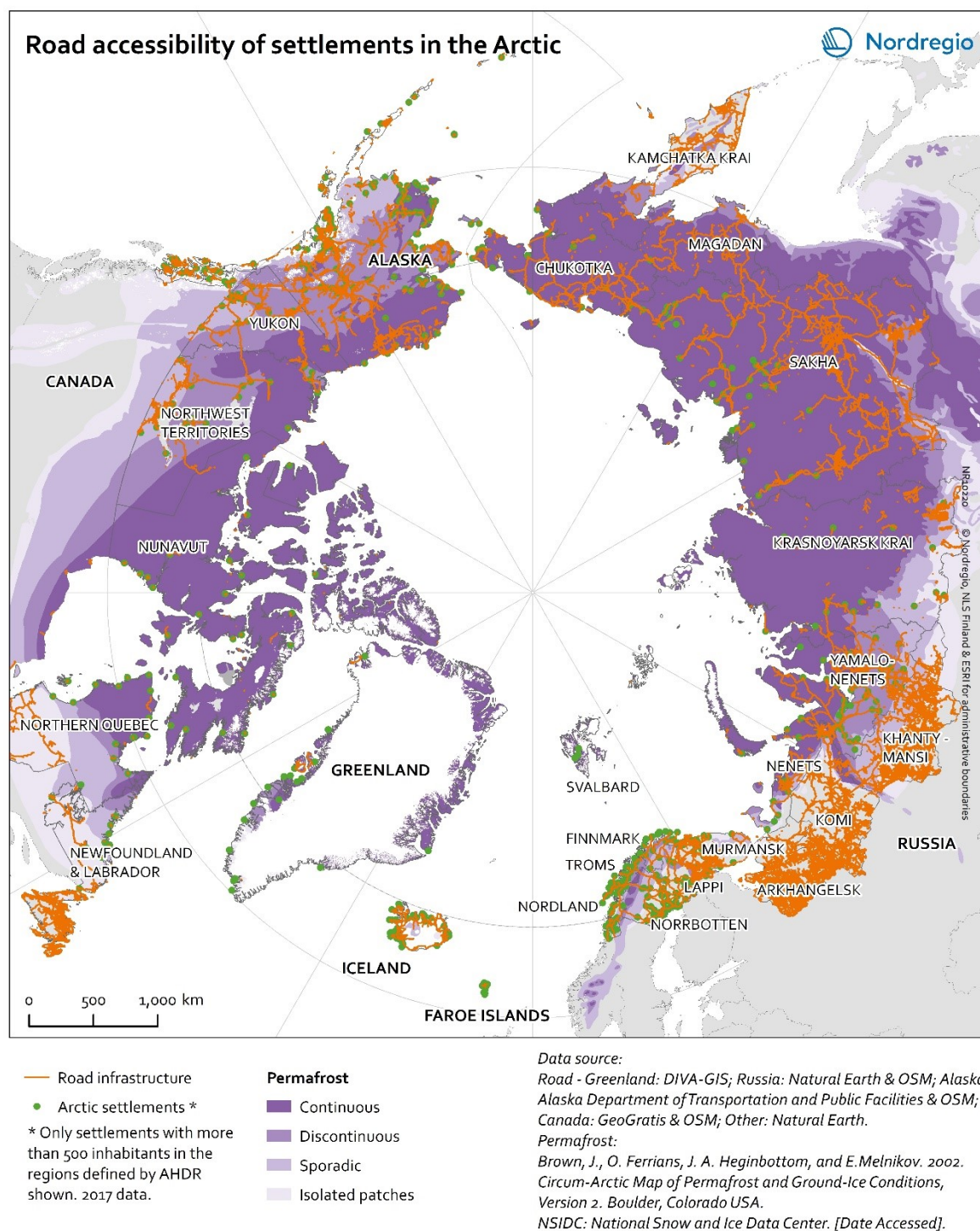


FIGURE 1: MAP OF THE DRAFT VERSIONS OF THE SETTLEMENT AND ROAD ACCESS DATABASES ON A PAN-ARCTIC

4 Compilation of local infrastructure data

4.1 General principles

Local data sets have been compiled for eight settlements in Greenland and one settlement in Svalbard in order to provide well-documented registrations of different types of Arctic infrastructure at high positional accuracy. The settlements selected for the detailed infrastructure registration are listed in Table 1.

For Svalbard, Longyearbyen was chosen as the main administrative centre with a wide range of infrastructures. Longyearbyen is located on continuous permafrost.

For Greenland, the settlements were chosen to span a range of different settings:

- Settlements of different size: from larger towns (Sisimiut: 5491 inhab., Ilulissat: 4563 inhab.) to small settlements (Sarfannuguit: 111 inhab., Oqaarsut: 27 inhab.) to catch the variation in infrastructure size and complexity (population data from Statistics Greenland, 2018)
- Settlements located in different geological settings: Settlements on sedimentary deposits (Qaanaaq, Kangerlussuaq), settlements primarily on bedrock (Sarfannuguit), and settlements in a mixed setting (Sisimiut, Ilulissat, Oqaatsut, Qeqertarsuaq, Uummannaq), to provide training data for the variation in background signature.
- Settlements at different geographical latitudes: From settlements in the high North in continuous permafrost (Qaanaaq, 76°N) to settlements at the southern limit of discontinuous permafrost (Sisimiut and Sarfannuguit, both at 66°N).

TABLE 1: TOWNS AND SETTLEMENTS SELECTED FOR DATA ANALYSIS IN GREENLAND AND SVALBARD

Settlement	Code	Region	GSV validated	Field validated
Ilulissat	ILU	Greenland	Yes	Yes
Kangerlussuaq	KAN	Greenland	Yes	Yes*
Oqaatsut	OQA	Greenland	Yes	Yes
Sisimiut	SIS	Greenland	Yes	Yes
Qeqertarsuaq	QEQ	Greenland	Yes	No
Qaanaaq	QNQ	Greenland	Yes	Yes
Sarfannuguit	SFN	Greenland	Yes	No
Uummannaq	UUM	Greenland	Yes	No
Longyearbyen	LYR	Svalbard	Yes	Yes*

* Distant infrastructures have only been validated by Google Street View.

The basic GIS themes with up-to-date infrastructure features were obtained from authoritative sources in the two regions (Asiaq Greenland Survey in Greenland and Lokalstyret in Longyearbyen, Svalbard). The original themes contain polygon features with sub-meter (decimetre) absolute positional accuracy.

In each settlement, individual infrastructures were selected for the registration, in order to ensure documentation of a wide range of different types of infrastructure:

- Transportation infrastructure: roads, airports, helipads, harbours
- Residential infrastructure: Houses, Apartment buildings
- Industrial infrastructure: Industrial buildings, cranes, containers, storage tanks, pipelines.

In the final dataset, each feature has been associated with attributes describing the type of infrastructure, the surface material (as visible from the satellite), the shape of the structure (vertical profile, i.e. pitched, flat, domed etc.), the geological background of the structure, and whether the structure is in active use or not. The full list of added attributes are available in Table 2 along with lists of the attribute values used. Attribute names begin with a capital 'N' to distinguish the added attributes from any attributes of the original theme (which have been retained for completeness). Where attributes values could not be established (information unavailable or attribute inappropriate for the type of infrastructure) a value of "NA" has been registered.

The attributes values were determined based on observations from available orthophotos, combined with local knowledge of the operator. All features attributes have been validated by use of Google Street View imagery (Google Street View is available for all the chosen settlements) and/or by field validation during site visits in the fall of 2018. Two attributes for each structure indicate which types of validation has been performed for the given structure.

For each structure that has been field validated, a photo is also provided of the structure. The naming convention of the photos is based on the three letter location code (see Table 1) and a three digit structure identification number, e.g. "ILU_001.jpg". In cases where several photos are available of the same infrastructure, an additional identifier is added to the filename, e.g. "_front" or "_roof".

4.2 Data set organization and publication

The final datasets of infrastructure registrations from Greenland and Svalbard have been compiled and will be available through the PANGAEA data repository at the following URLs:

- Greenland data: <https://doi.pangaea.de/10.1594/PANGAEA.895949>
- Svalbard data: <https://doi.pangaea.de/10.1594/PANGAEA.895950>

The data sets have each been assigned digital object identifiers (DOI), and will be available by early 2019.

Final publication of the Longyearbyen data is subject to our possibility to obtain the appropriate permissions. If the licensing of the themes obtained restrict the publication of derived products, the Longyearbyen dataset will be for internal project use only.

For each settlement, the data set consists of two shape files, one for polygon features (buildings, roads etc.) the other has line features (e.g. pipelines). A third shape file provides a polygon feature enclosing an area of similar properties as the corresponding settlement, but free of any known infrastructures. This area can be used as a reference area to determine a baseline signature of the settlement in question.

Photos are collected in separate zip-files, one for every settlement where photos are available.

The file naming conventions are:

- Polygon theme: [loc.code]_polygons.shp,
- Line theme: [loc.code]_lines.shp
- Reference theme: [loc.code]_reference_area.shp
- Photos: [loc.code]_photos.zip

TABLE 2: LIST OF ATTRIBUTES AND ATTRIBUTE VALUES USED IN THE INFRASTRUCTURE REGISTRATION DATA SETS.

Attribute	Description	Attribute values
N_ID	Structure identification	[loc.code] [3 digit ID]
N_Type	Type of structure	Residential building, Public building, Industrial building, Mooring, Floating dock, Crane, Road, Storage tank, Container, Airstrip, Helipad, Pipeline
N_Material	Surface material	Roofing felt, Wood, Metal, PVC, Plastic, Asphalt, Gravel, Wood, Concrete, Slates, Fiber tiles, Crushed rock
N_Background	Background material	Bedrock, Sediments, Mixed, Sea, River
N_Shape	Shape of structure	Pitched, Domed, Arched, Sloped, Flat, Linear, Barrel-shaped
N_Active	Is structure in active use?	Yes, No
N_GSV validated	Have attributes been validation by Google Street View?	Yes, No
N_Field validated	Have attributes been field validated?	Yes, No
N_Comments	Any additional remarks	-

5 Infrastructure examples

This chapter contains examples of infrastructures from the two Greenlandic settlements Ilulissat and Oqaatsut, as well as the Svalbard settlement Longyearbyen.

5.1 Ilulissat

Ilulissat is a town in western Greenland located 350 km north of the Arctic circle. The town has 4563 inhabitants (as of January 2018, Statistics Greenland, 2018). Residential buildings are approximately distributed by 41% percent of single-family houses, 20% semi-detached houses and 39% apartments in multi-storey buildings. Fishing is the main industry in the town, but the harbour is used for multiple purposes including trawler quay, shipping, passenger transport and tourist quay. Furthermore, there are multiple floating docks for private and small tourist boats. The town also has a medium sized airport with an 845 m asphalt runway. (Qaasuitsup Kommunia, 2018).

The figures below show examples of the different types of infrastructures registered for Ilulissat and their attribute values in the database.



N_ID:	ILU_020
N_Type:	Residential building (Private)
N_Material:	Roofing felt
N_Shape:	Pitched
N_Background:	Mixed



N_ID:	ILU_013
N_Type:	Residential building (Apartment)
N_Material:	Roofing felt
N_Shape:	Sloped
N_Background:	Bedrock



N_ID:	ILU_031
N_Type:	Industrial building (Fishing factory)
N_Material:	Roofing felt
N_Shape:	Sloped
N_Background:	Bedrock



N_ID:	ILU_017
N_Type:	Road (Paved)
N_Material:	Asphalt
N_Shape:	Flat
N_Background:	Mixed



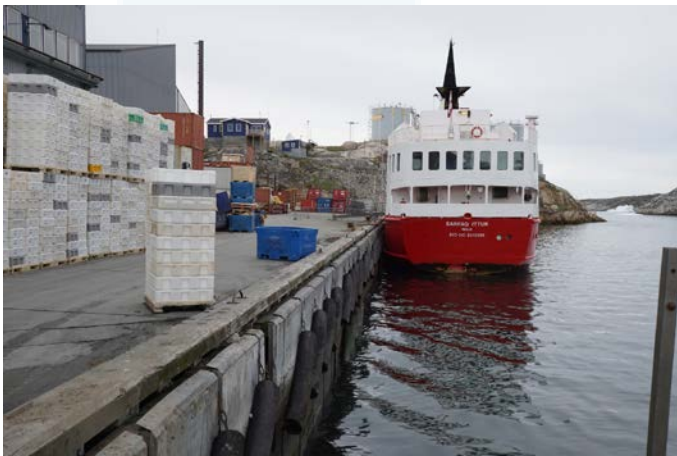
N_ID:	ILU_011
N_Type:	Road (Unpaved)
N_Material:	Gravel
N_Shape:	Flat
N_Background:	Bedrock



N_ID:	ILU_049
N_Type:	Airstrip
N_Material:	Asphalt
N_Shape:	Flat
N_Background:	Crushed rock (embankment)



N_ID:	ILU_037
N_Type:	Floating dock
N_Material:	Wood
N_Shape:	Flat
N_Background:	Sea



N_ID:	ILU_040
N_Type:	Mooring
N_Material:	Concrete blocks
N_Shape:	Flat
N_Background:	Sea



N_ID:	ILU_032
N_Type:	Fixed crane
N_Material:	Metal
N_Shape:	-
N_Background:	Gravel



N_ID:	ILU_035
N_Type:	Storage tanks
N_Material:	Metal
N_Shape:	Domed
N_Background:	Bedrock (Concrete basement)



N_ID:	ILU_006
N_Type:	Containers
N_Material:	Metal
N_Shape:	Flat
N_Background:	Gravel



N_ID:	ILU_065
N_Type:	Pipeline
N_Material:	Metal
N_Shape:	Linear
N_Background:	Bedrock

5.2 Oqaatsut

Oqaatsut is a settlement with population of 27 inhabitants (as of January 2018, Statistics Greenland, 2018) situated 18 km north of Ilulissat. The buildings are mainly single-family houses. Furthermore, there is a fishing factory in the settlement (Qaasuitsup Kommunia, 2018).

The figures below give examples of the different types of infrastructures registered for Oqaatsut and their attribute values in the database.



N_ID:	OQA_017
N_Type:	Residential building (Private)
N_Material:	Roofing felt
N_Shape:	Pitched
N_Background:	Bedrock



N_ID:	OQA_019
N_Type:	Industrial building
N_Material:	Metal
N_Shape:	Pitched
N_Background:	Bedrock



N_ID:	OQA_032
N_Type:	Road (Trail)
N_Material:	Gravel
N_Shape:	Flat
N_Background:	Sediments



N_ID:	OQA_002
N_Type:	Floating dock
N_Material:	Wood
N_Shape:	Flat
N_Background:	Sea



N_ID:	OQA_020
N_Type:	Helipad
N_Material:	Wood
N_Shape:	Flat
N_Background:	Bedrock



N_ID:	OQA_026
N_Type:	Mooring
N_Material:	Wood
N_Shape:	Flat
N_Background:	Sea



N_ID:	OQA_025
N_Type:	Fixed crane
N_Material:	Metal
N_Shape:	-
N_Background:	Wood (Harbour)



N_ID:	OQA_023
N_Type:	Storage tank
N_Material:	Metal
N_Shape:	Barrel-shaped
N_Background:	Bedrock



N_ID:	OQA_033
N_Type:	Pipeline
N_Material:	Metal
N_Shape:	Linear
N_Background:	Bedrock

5.3 Longyearbyen

Longyearbyen located at high north, N78°25' E15°37' (Instanes and Anisimov, 2008), is the largest settlement and the administrative centre of Svalbard, Norway, and has a population of 2070 (Grydehøj, 2014).

Longyearbyen is located in the Longyear Valley and on the shore of Adventfjorden, a bay of Isfjorden located on the west coast of Spitsbergen. The town is the world's northernmost settlement of any kind with more than 1000 permanent residents.

For most selected infrastructures in Longyearbyen, two photos are provided (one front view and one roof close-by view) and its reference location in the overall GIS database. The figures below give examples of the different types of infrastructures registered for Longyearbyen and their attribute values in the database.



N_ID:	LYR001
N_Type:	Public building
N_Material:	Metal
N_Shape:	Pitched
N_Background:	Sediments



N_ID:	LYR002
N_Type:	Public building
N_Material:	Roofing felt
N_Shape:	Pitched
N_Background:	Sediments



N_ID: LYR003
 N_Type: Industry building
 N_Material: Roofing felt
 N_Shape: Domed
 N_Background: Sediments



N_ID: LYR004
 N_Type: Industry building
 N_Material: Concrete
 N_Shape: Flat
 N_Background: Sediments



N_ID: LYR005
 N_Type: Industry building
 N_Material: Metal
 N_Shape: Pitched
 N_Background: Sediments



N_ID: LYR006
 N_Type: Industry building
 N_Material: Roofing felt
 N_Shape: Pitched
 N_Background: Sediments



N_ID:	LYR007
N_Type:	Public building
N_Material:	Roofing felt
N_Shape:	Sloped
N_Background:	Sediments



N_ID:	LYR008
N_Type:	Public building
N_Material:	Slates
N_Shape:	Pitched
N_Background:	Sediments



N_ID:	LYR012
N_Type:	Industry building
N_Material:	Roofing felt
N_Shape:	Pitched
N_Background:	Sediments



N_ID:	LYR013
N_Type:	Industry building
N_Material:	Metal
N_Shape:	Pitched
N_Background:	Sediments



N_ID:	LYR014
N_Type:	Industry building
N_Material:	Roofing felt
N_Shape:	Pitched
N_Background:	Sediments



N_ID:	LYR015
N_Type:	Industry building
N_Material:	Roofing felt
N_Shape:	Pitched
N_Background:	Sediments



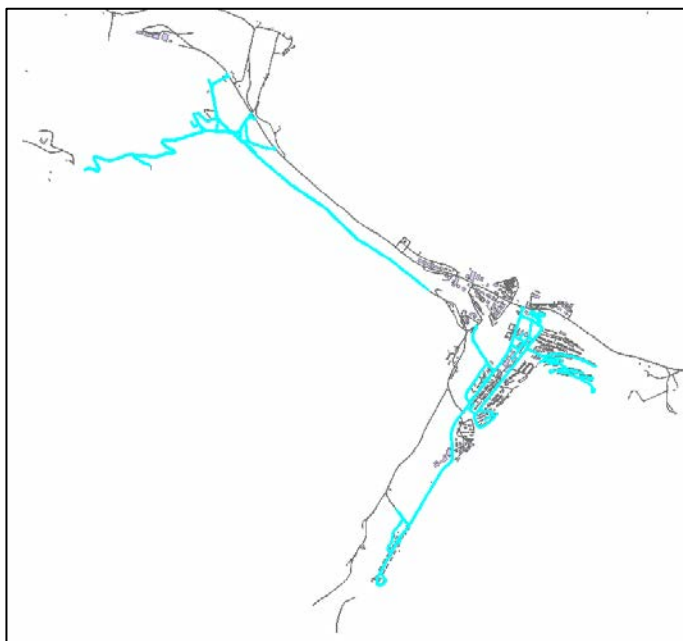
N_ID:	LYR016
N_Type:	Public building
N_Material:	Wood
N_Shape:	Pitched
N_Background:	Sediments



N_ID:	LYR020
N_Type:	Roads
N_Material:	Asphalt
N_Shape:	Flat
N_Background:	Sediments



N_ID:	LYR021
N_Type:	Roads
N_Material:	Gravel
N_Shape:	Flat
N_Background:	Sediments



Summary of all the roads selected in Longyearbyen for the dataset (highlighted with cyan color)

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